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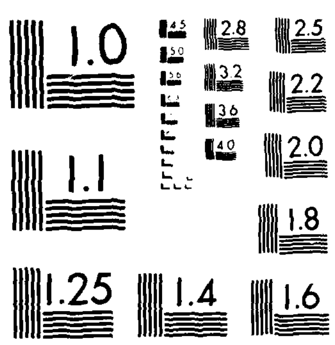
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US Army Corps of Engineers
Huntsville Division

AD-A153 685

DIRECT DIGITAL CONTROL STUDY

HNDSP -85-105-EDME
FEBRUARY 1985

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ENERGY MANAGEMENT, MONITORING

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

THE PURPOSE OF THIS REPORT IS TO DESCRIBE THE STATE OF THE ART OF DIRECT DIGITAL CONTROL (DDC) SYSTEM TECHNOLOGY THAT MONITORS AND CONTROLS MECHANICAL AND ELECTRICAL SYSTEMS FOUND IN GOVERNMENT FACILITIES. A DDC SYSTEM CAN OPERATE EITHER AS A STAND-ALONE CONTROL SYSTEM OR AS AN EXTENSION TO AN ENERGY MONITORING AND CONTROL SYSTEM (EMCS).

NOTICE

This report has been prepared by Kling-Lindquist, Inc. of Philadelphia, Pennsylvania under contract to the U.S. Army Corps of Engineers, Huntsville Division. The tables in this report, which summarize DDC manufacturers' responses to a questionnaire.

Ten of the thirteen manufacturers that responded to the Questionnaire provided written statements that verified the data summarized in Tables 2-1 to 2-9 and Table 3-1. The remaining three manufacturers, identified in the Tables as Companies "A", "B" and "C" did not provide such authorization. Until written authorization is received, these manufacturers will remain anonymous. A copy of the letter requesting verification of data included in the report appears in Appendix D.

A1

EXECUTIVE SUMMARY

Scope of Work

The purpose of this report is to describe the state-of-the-art of direct digital control (DDC) system technology that monitors and controls mechanical and electrical systems found in Government facilities. A DDC system can operate either as a stand-alone control system or as an extension to an Energy Monitoring and Control System (EMCS).

General

Direct digital control systems are self-contained computer based systems which monitor and control processes in accordance with predetermined strategies.

This report addresses the commercial-type DDC systems, in which sensors and controls are connected to a control panel. Control devices are modulated directly by the DDC system in accordance with established algorithms. Unlike industrial-type DDC systems, commercial-type DDC systems do not have a specific address for each control point position.

The results presented in this report are based on data provided by DDC equipment manufacturers' responses to a questionnaire developed by Kling/Lindquist (K/L) and from K/L engineering experience with DDC design and installation. At the present time, a number of vendors provide commercial-type DDC system panels which handle 4 to 256 analog and digital input/output points. The DDC systems use either 8 bit or 16 bit microprocessors with a minimum of 64 Kbytes of total memory. These DDC system panels typically provide stand-alone operation without the need of a supervisory or central control system such as an EMCS. DDC systems as a general rule use standard off-the-shelf electrical devices. DDC systems require digital to analog converters for actuating pneumatic control devices.

Hardware/Software

DDC panels are manufactured to handle a specific maximum number of analog and digital input and output (I/O) points. The actual number of points that a DDC panel can handle depends upon the memory available after memory has been allocated for the operating system and applications programs. For example, a DDC system with a maximum number of 32 I/O points may only be able to monitor and control 16 I/O points in order for the panel to contain application software for energy management of a variable air volume system.

Standardized application programs to control the types of mechanical and electrical equipment from most manufacturers found in Government facilities are presently available and can be implemented in DDC systems. Typical DDC application programs include Optiumum Start/Stop, Duty Cycling, and Demand Limit. Customized programs must be developed for mechanical and electrical equipment requiring non-standard application programs.

DDC systems can be programmed and can run diagnostics with the use of portable devices such as CRTs, a printer or other dedicated terminal devices. The man-machine interfaces for the DDC systems vary among manufacturers and can either use alphanumeric or full english words. The operation of these man machine interfaces and the operation of the DDC systems require specialized training by facility operating personnel.

Installation

The installation of the DDC panel systems presents no technical problems. DDC systems can be installed by the manufacturer using currently available instrumentation and control devices in accordance with the National Electric Code. The installation of individual DDC panel systems prior to acceptance can be typically completed within two to three months after shop drawing approval.

DDC startup and checkout can present problems not found with conventional pneumatic and electrical/electronic control systems. The availability and technical ability of the manufacturer's personnel required to startup and checkout the DDC system is not always adequate. The location and size of the project in many cases dictates the type of personnel available from the manufacturer to install DDC systems. Therefore, the location and size of the manufacturer's support organization that serves the facility on which the DDC system is located and their familarity with the DDC system equipment will have a great impact on the completion and the installation quality of the DDC System.

Maintenance And Operations

DDC systems are generally easier to maintain than conventional systems with pneumatic controls because there are fewer parts, and these parts can be easily replaced when they fail. In addition, DDC systems do not have the calibration problems that are common to conventional systems with pneumatic controls.

The lack of standardization among various manufacturer's DDC system operation, maintenance and programming procedures will cause problems in Government facilities where more than one type of DDC system has been installed. Government personnel will have to be trained for each type of installed system. Differences in DDC system maintenance requirements

among manufacturers may force the Government to either develop a specialized maintenance crew or purchase maintenance contracts from the equipment manufacturers. In most cases, spare parts and diagnostic equipment must be purchased and stored for each type of DDC system.

Government personnel who have no background in electronic equipment will need retraining to become familiar with the operations of DDC systems.

Additional training is required for facility personnel to become familiar with programming techniques for each type of installed DDC in order to effect changes in operating setpoints and application programs.

Communication Interfaces

Communication interfaces exist for data exchange between DDC system and EMCS systems of the same manufacturer. At the present time, no standard communications interface protocol exists for communication among DDC systems of different manufacturers. No standards exist or are being proposed for DDC systems to communicate with DDC systems or with EMCS systems of different manufactuers. The absence of DDC system interface protocols presents a problem similar to the one Government has experienced with EMCS systems. Interface protocols are manufacturers' proprietary information and are therefore subject to the Federal Acquisition Regulations (FAR) regarding rights in software and technical data.

Costs

Most of the DDC manufacturers responding to the questionaire provided some budget cost information on standard, stand-alone DDC equipment packages. This data and information on recent bid prices of DDC systems in non-government facilities indicates that DDC systems are cost competitive with conventional control systems in facilities containing mechanical systems requiring stand-alone energy management programs. The use of DDC systems as the primary control system in conjunction with an EMCS of the same manufacturer can save up to 20 percent of the installation cost of separate pneumatic or electric control systems and EMCS. The savings are attributed to a reduction in wiring and in the number of instrumentation and control devices needed.

Engineering Documentation Requirements

The design of DDC systems requires that the DDC contract documents prepared for bid are as complete as the bid documents currently prepared for EMCS projects. All instrumentation and control devices must be shown and located. Detailed sequences of operation must be prepared for every mechanical and electrical system controlled from the DDC system in order for the contractor to program the DDC system.

Advantages and Disadvantages of DDC Systems

DDC systems can provide more accurate control with less maintenance than systems with pneumatic or electric/electronic controls. DDC systems inherently provide proportional, derivative and integral close loop control (three mode control). Three mode control capabilities can reduce the amount of energy consumed to provide heating and cooling to a facility. Changes in DDC system application software allows for variation in the equipment sequence of operation without physical changes to the installed instrumentation and control devices. Controlled equipment operating setpoints can be changed without recalibration of instrumentation devices. Changes to the application software, operating setpoints and parameters require the use of trained personnel.

Recommendations

It is recommended that the U.S. Army Corps of Engineers embark on a program to adopt DDC systems as the primary control system in Government facilities only after the following items have been addressed and resolved:

A. Develop a standard communications protocol for the interface of DDC systems and EMCS of different manufacturers. Requirements must be established for delivery of manufacturer proprietary data to the Government for its own use and for third party use (EMCS Manufacturer). For interfacing purposes, standard communication interface parameters must be considered and should be based on one of the existing Local Area Networks (LAN) or other parameters currently being developed by the computer industry.

B. Unless a standard communications protocol is developed by the DDC industry, consider the installation of DDC system of only one manufactuer in any one Government installation. This practice will facilite DDC system interface with an EMCS when it is required.

C. Establish policies by which DDC systems of different manufacturers will be maintained and system operational changes performed, (such as setpoint changes). It is conceivable that a Govenment installation may contain DDC systems from more than one manufacturer, and therefore Government facility personnel may not be able to cope with the variations in equipment maintenance and operation.

D. Establish minimum design and documentation requirements for the construction contracts and for contractor furnished data that the Government will need after the DDC system is installed.

E. Develop a Corps of Engineer Guide Specification for DDC Systems.

The lessons learned by the Government in the procurement of EMCS apply to DDC Systems. Similar problems experienced by the Government in expanding EMCS can be expected with DDC Systems when the DDC System is required to be interfaced with an EMCS of different manufacturers. Therefore, Government requirements must be established for contractor furnished data that the Government will need after the DDC system is installed.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

This Chapter presents a general description of DDC system hardware and software. Features that are common to most DDC systems are described. Subsequent Chapters present a more detailed discussion of DDC system characteristics and show variations among the systems from various manufacturers.

1.2 DESCRIPTION OF DDC

Direct digital control (DDC) systems are self-contained computer-based systems which monitor and control processes in accordance with predetermined strategies. Processes that can be monitored and controlled using DDC include the mechanical and electrical equipment used in environmental systems for comfort conditioning. DDC systems can replace the conventional monitoring and control equipment which utilize pneumatic or electric/electronic controllers to perform control functions. Figure 1-1 illustrates a typical closed loop control system using the conventional method of monitoring and control. Figure 1-2 shows how the DDC system replaces the conventional controller. For new installations, the advantages of DDC systems include:

- Replacement of conventional sensors and controllers which require periodic maintenance and calibration with more reliable electronic components.

- Fewer components to install and maintain.

- Greater monitoring accuracy and control precision.

- Repair within the DDC panel generally involves simple replacement of a plug-in circuit board.

- Ease of modifying control strategies without rewiring or repiping of existing installations.

DDC systems are best suited to two-state signals such as on/off or open/close signals (called digital inputs and outputs). These systems can also receive and generate signals that vary with time such as temperature and pressure (called analog signals) using digital to analog converters.

TABLE 2-4
DDC SYSTEM TRANSMISSION AND INTERFACE
SUMMARY OF QUESTIONNAIRE RESPONSES

MANUFACTURER	TRANSMISSION MEDIA BAUD RATES: COAXIAL CABLE	TWISTED PAIR	DEDICATED PHONE	DIAL UP PHONE	FIBRE OPTICS	TRANSMISSION: MAX DATA TRANSMISSION LINKS/CENTRAL COMPUTER	RESPONSE TIME AT FULL LOAD (DDC TO CENTRAL)	MAX DDC PANELS PER 1200 BAUD LINE	INTERFACE: WITH ANOTHER EMCS	WITH PNEUMATIC/ ELECTRONIC CONTROLS
1 ANDOVER		9600	1200	1200	19200	128		(19.2K BAUD)-16	NO	YES
2 ANDERSON CORNELIUS	1200-9600	1200-9600	300-1200	300-1200	1200-9600	NO LIMIT	1.6 SEC	UNLIMITED	YES	YES
3 ATLANTIC ENERGY		300-9600		300-1200		64	2-3 MIN	64	YES	YES
4 CLIMATRON			YES	YES		32,128,256	5 SEC	16	YES	YES
5 COMPUTER SCIENCES		300-9600	300-9600	300-9600	300-9600	16	2 SEC	16	YES	YES
6 ENERGIST				300					YES	YES
7 HONEYWELL		600-2400	600-1200	600-1200	600-2400	9	0.3-0.5 SEC	8	NO	YES
8 JOHNSON CONTROLS		300-9600	300-4800	300-1200		8	6 SEC	8	NO	YES
9 RAYTHEON	110-9600	110-9600	110-9600	110-1200		24	10 SEC	3	NO	YES
10 TOUR AND ANDERSON		300-9600	300-1200	300-1200		AT LEAST 2	1.5 SEC/RPU	50	YES	YES
11 COMPANY A		2400-9600				16	6 SEC	NOT APP.	YES	ELECRONIC ONLY
12 COMPANY B		1200-9600	1200	1200		4	1 MIN (4 SEC FOR ALARMS)	50	YES	YES
13 COMPANY C		1200-4800	300-1200	300-1200		6	LESS THAN 5 SEC 80 PERCENT OF TIME	32	POSSIBLE	YES

TABLE 2-3
DDC HARDWARE FEATURES
SUMMARY OF QUESTIONNAIRE RESPONSES

	MANUFACTURER	MODEL TYPE	ON-OFF LINE SWITCH	SELF TEST SWITCH	RESET SWITCH	REAL TIME CLOCK	COMMUN INTERFACE	AUTO ANS/ AUTO ORIG	NO. PERIPHER PORTS	MUX WITH: LOCAL IO	MUX WITH: REMOTE IO	BUILT IN DIAG/PROG PANEL	BUILT IN I/O	REMOTE I/O	LOCAL DISPLAY & CNTL PANEL	PROCESSOR (BITS)	EQUIPMENT FOR PROGRAMMING	EQUIPMENT FOR DIAGNOSTICS
1	ANDOVER	AC256	NO	NO	YES	YES	RS232C	YES	2	YES	YES	NO	YES	YES	YES	8	PDD	PDD
		AC8	NO	YES	YES	YES	RS232C	YES	2	YES	YES	NO	YES	YES	YES	8	PDD	PDD
2	ANDERSON CORNELIUS	MCU-500	N/A	YES	YES	YES	RS232C,	NO	1			YES	YES		YES	16	BUILT IN	BUILT IN
		MCU-250	N/A	YES	YES	YES	RS422	YES	3			YES	YES		YES	16		
		MCU-260	N/A	YES	YES	YES		YES	NO LIMIT			YES	YES		YES	16		
3	ATLANTIC ENERGY	AET 816/32	YES		YES	YES	RS232C	YES	2	NO	NO	YES	YES		YES	8	CENTRAL, PDD	TERMINAL
		AET 448	YES		YES	YES	RS232C	YES	1	NO	NO	YES	YES		YES	8	CENTRAL, PDD	TERMINAL
4	CLIMATRON	4000	YES	NO	YES	YES	ASYNCH.	NO	3	YES	YES	YES	YES	YES	YES	8	REPLACE PROM	PDD
		2100	YES	NO	NO	YES	RS232C	YES	2	YES	YES	YES	YES	NO	YES	8	REPLACE PROM	PDD
5	COMPUTER SCIENCES	INFOSCAN	YES	YES	YES	YES	RS232C	OPTIONAL	1	YES	YES	YES	YES	YES	NO	8	CENTRAL, TEST SET	CENTRAL, TEST SET
6	ENERSIST		NOT STD	NO	NO	YES	RS232C		24	YES	YES	YES			YES	8	TERMINALS	TERMINALS
7	HONEYWELL	R7510	NO	NO	NO	YES	RS422	YES	1	YES	NO	OPTION	YES	NO	OPTIONAL	8	OPER.'S TERMINAL	OPER.'S TERMINAL
8	JOHNSON CONTROLS	DSC-8500	NO	YES	YES	YES	FSK	YES	2	YES	YES	YES	YES	YES	YES	16	FIELD LOAD DEVICE	BUILT IN, PDD
9	RAYTHEON	FID.LCM	YES	YES	YES	YES	RS232C,	YES	1	1	6	YES	YES	YES	YES	6	PDD	PDD
		FID.MUX	YES	YES	YES	YES	RS448		1	1	6	YES	YES	YES	YES	8	PDD	PDD
10	TOUR AND ANDERSON	V2	YES	NO	YES	YES	TALME,	NOT	2	YES	YES	NO	YES		YES	8	CENTRAL	BUILT IN
		V3A	YES	NO	YES	YES	ASCII	BUILT IN	2	YES	YES	YES	YES		YES	8	CENTRAL	BUILT IN
		V3D	YES	NO	YES	YES			2	YES	YES	YES	YES		YES	8	CENTRAL	BUILT IN
11	COMPANY A		NO	YES	YES	YES	RS232C	NO	24	YES		YES	YES	NO	YES	8	DISC	BUILT IN
12	COMPANY B		YES	YES	YES	YES	YES	YES	4			YES	YES		YES	8	CENTRAL	CENTRAL, PDD
			YES	YES	YES	YES	YES		4			YES	YES		YES	16	CENTRAL	CENTRAL, PDC
13	COMPANY C		NO	NO	NO	YES	RS232C,	YES	1	YES	YES	YES	YES	YES	YES	16	BUILT IN DEVICE	BUILT IN DEVICE
			NO	NO	NO	YES	RS422		1	NO	YES	NO	NO	NO	NO	15	BUILT IN DEVICE	BUILT IN DEVICE

TABLE 2-2
DDC SYSTEM MEMORY CAPABILITIES
SUMMARY OF QUESTIONNAIRE RESPONSES

	MANUFACTURER	MODEL TYPE	TOTAL RAM	TOTAL PROM	OPER. SYSTEM RAM	DEFAULT PARAM RAM	APPLICA. SOFTWARE RAM	OPER. SYSTEM ROM	DEFAULT PARAM ROM	APPLICA. SOFTWARE ROM	CALCULATIONS FOR MEMORY REQUIREMENTS
1	ANDOVER	AC256	128K	64K	NOT REQUIRED		80K	32K			MEMORY SIZED FOR 320 CONTROL LOOPS.
		AC8	32K	64K	NOT REQUIRED		16K	32K			MEMORY SIZED FOR 32 CONTROL LOOPS.
2	ANDERSON CORNELIUS	MCU-500	24K	40K	N/A	N/A	N/A	N/A	N/A	N/A	MEMORY SIZED TO MEET MAX NO. OF LOOPS.
		MCU-250	80K	64K	N/A	N/A	N/A	N/A	N/A	N/A	MEMORY SIZED TO MEET MAX NO. OF LOOPS.
		MCU-260			N/A	N/A	N/A	N/A	N/A	N/A	MEMORY SIZED TO MEET MAX NO. OF LOOPS.
3	ATLANTIC ENERGY	AET 816/32	16K	16K	4K	1K	7.5K	16K	0	0	16 APPLIC. PROGRAMS WITH 64 LINES/PROG & 59 BYTES/LINE
		AET 443	8K	16K	2K	1K	3.5K	16K	0	0	8 APPLIC. PROGRAMS WITH 64 LINES/PROG & 59 BYTES/LINE
4	CLIMATRON	4000	256K	3000K	6K,2K		1K,1K	600K	285K	2000K	MEMORY SIZED TO MEET MAXIMUM NUMBER OF LOOPS.
		2100	8K	16K	1K		4K	12K	1K	12K	MEMORY SIZED TO MEET MAXIMUM NUMBER OF LOOPS.
5	COMPUTER SCIENCES	INFOSCAN	16K	32K	3K	13K	13K	20K	12K	12K	20 WORDS PER DDC POINT
6	ENERGIST		4K	16K	4K						
7	HONEYWELL	87510	16K	64K		........8K........		48K		16K	ALL CONTROL LOOPS AND PROG REQ FOR 6-8 HVAC UNITS = 8K
8	JOHNSON CONTROLS	DSC-8500	45K	40K	2K	.............PROPRIETARY DATA..........					
9	RAYTHEON	[illegible]	32K	32K	1K		31K	32K	32K	32K	
		[illegible]	32K	32K	1K		31K	32K	32K	32K	
10	TOUR AND ANDERSON	V2	4K	20K	20K	3K	1K	.......OPTIONAL.......			DEPENDS ON WHAT IS BEING CONTROLLED AND HOW.
		V3A	8K	32K	32K	7K	1K	.......OPTIONAL.......			DEPENDS ON WHAT IS BEING CONTROLLED AND HOW.
		V30	8K	32K	32K	7K	1K	.......OPTIONAL.......			DEPENDS ON WHAT IS BEING CONTROLLED AND HOW.
11	COMPANY A		16K	16K							EACH FIELD DEVICE HAS 32 AI,16 AO,64 DI,60 DO, 40 ANALOG CONFIG. LINES,220 DIGITAL CONFIGURATION LINES
12	COMPANY B		16K	4K	12K	2K	2K				NO LOCAL MEMORY LIMIT. LIMIT ON PHYSICAL OUTPUTS ONLY.
13	COMPANY C		32K	128K	..................PROPRIETARY..........................						
			32K	32K							

TABLE 2-1
DDC SYSTEM HARDWARE CONFIGURATION
SUMMARY OF QUESTIONNAIRE RESPONSES

	MANUFACTURER	MODEL TYPE	STAND ALONE	INTERFACE WITH CENTRAL	CAN INCLUDE CENTRAL	....TOTAL I/O POINTS.... ANALOG INPUTS	ANALOG OUTPUTS	DIGITAL INPUTS	DIGITAL OUTPUTS	PULSE ACCUMUL.	CONTROL LOOPS	....MAXIMUM POINTS PER CONTROL LOOP.... ANALOG INPUTS	ANALOG OUTPUTS	DIGITAL INPUTS	DIGITAL OUTPUTS	PULSE ACCUMUL.
1	ANDOVER	AC256 AC8	YES	YES	YES	32-512 (I/O's ARE UNIVERSAL) 14 (I/O's ARE UNIVERSAL)			16-256 8		320 32	512 (I/O's ARE UNIVERSAL) 14 (I/O's ARE UNIVERSAL)			256 8	512 14
2	ANDERSON CORNELIUS	MCU-500 MCU-250 MCU-260	YES	YES	YES	192 240 NO LIMIT	80 240 NO LIMIT	256 240 NO LIMIT	80 240 NO LIMIT	256 240 NO LIMIT	80 120 NO LIMIT	192 216 NO LIMIT	255 216 NO LIMIT	80 216 NO LIMIT	80 216 NO LIMIT	256 240 NO LIMIT
3	ATLANTIC ENERGY	AET 816/32 AET 448	YES YES	YES YES	YES YES	16 8	0	8 4	8 4	44 20	8 8	16 8	8 NA	8 8	8 8	44 20
4	CLIMATRON	4000 2100	YES YES	YES YES	YES YES	480 39	64 8	496 24	512 64	1 2	256 64	32 4	16 1	4 1-8	16 8	1
5	COMPUTER SCIENCES	INFOSCAN	YES	YES	YES	..........APPROX 50 LOOPS PER FID..........................						10	10	10	10	10
6	ENERGIST		YES	YES	NO	2-48	2-48	8-192	8-192	8	256/#PTS	48	48			8
7	HONEYWELL	R7510	YES	YES	YES	8	8	8	8			..............NO LIMIT...................				
8	JOHNSON CONTROLS	DSC-8500	YES	YES	YES	15	8	8	16	8		15	8	8	16	8
9	RAYTHEON	FID/LOM FID/MUX	YES	NO	YES	8 8-40	4 4-24	8 8-48	8 8-48	1 1-4	30 30	8 8-40	8 8-48	4 4-24	8 8-48	1 1-4
10	TOUR AND ANDERSON	V2 V3A V3D	YES YES YES	YES YES YES	YES YES YES	16 16 16	0 6 0	16 16 16	16 10 16	16 16 16	12 12 12	12 ......UNLIMITED/NOT APPLICABLE............. 12 ......UNLIMITED/NOT APPLICABLE............. 12 ......UNLIMITED/NOT APPLICABLE.............				
11	COMPANY A		YES	NO	NO	1000	500	2000	2000	N/A	500	32	64	16	64	
12	COMPANY B		YES	YES	YES	16	12	16	16	4	12	2	2	2	2	4
13	COMPANY C		YES	NO	YES	16 64	8 64	10 128	8 128	16	125 256	.....DETERMINED BY USER THRU.......... ...PROGRAMMING. NOT HARDWARE DEPENDENT....				2 16

The current equipment cost of DDC panels (not including installation) ranges from $2,500 for the smaller panels with 32 points to $10,000 for larger DDC panels with over 100 I/O points. The total number of I/O points is not a good indicator of DDC system cost for larger systems. Other features such as the number of peripheral ports, types of software system memory, and communications capabilities also impact DDC cost.

DDC systems are generally cost competitive with conventional pneumatic control systems if the facility in which the DDC System is being installed requires energy management applications programs.

least a couple of energy management programs. DDC systems may cost less than systems with pneumatic controls as the number of energy management program requirements increase. Table 2-9 summarizes the costs for stand-alone DDC system panels.

2.9 SUMMARY OF DDC CAPABILITIES AND LIMITATIONS

Most DDC systems can operate as stand-alone units or as part of a larger EMCS with a central computer. If the DDC is to interface with a central computer, communications protocol must be provided. Communications protocol must also be provided if a DDC system must communicate with a DDC system from a different manufacturer. At the present, the problems of obtaining communications protocol from manufacturers have imposed real constraints on interfacing DDC Systems of different manufacturers.

Most DDC systems use english words for man-machine interface. However, the methods of system operation are likely to vary among DDC systems from different manufacturers. Operators in facilities with different types of systems must be familiar with these variations.

All DDC systems provide information on point status (on/off), parameter values, change of state, and equipment failure. This data can be displayed at the DDC panel also and can be displayed at the central computer if the DDC panel is configured as part of the EMCS. Most EMCS-type applications programs are also readily available for stand-alone DDC use. Typical DDC applications programs include equipment start/stop, duty cycling, day/night setback, temperature reset programs, and economizer/enthalpy control programs. Special control requirements that are job specific are likely to require new program development or modifications to existing programs. Program modifications require trained personnel who are familiar with the language used by the DDC System.

In addition to the proportional control method used by conventional control systems, DDC systems use more sophistocated control methods to reduce offset and improve control accuracy. These methods include proportional/integral (PI) and proportional/integral/deviative control (PID). DDC systems can use pulse width modulation, proportional electric/electronic control of analog devices, or transduced pneumatic signals for two position or proportional pneumatic control. Most DDC systems can interface with existing electric and pneumatic controls through a digital to analog transducer.

The mean time between DDC panel failures (not including sensors or control devices) ranges from 4,000 hours to 30,000 hours, depending on the manufacturer. The mean time to repair ranges from one hour to 24 hours for most DDC panels. Spare parts for each manufacturer's DDC system can be stored on site so that the central processing unit (CPU), I/O, power supply and memory boards can be replaced in the field.

when power failure exceeds battery backup capability. Typically, operating software is resident in non-volatile memory. Some DDC systems also contain application software and operating parameters in non-volatile memory. Software that is resident in volatile memory is lost when power failure exceeds battery backup capability. After power is restored, software that was lost is reloaded using a portable diagnostic device or by downloading the software from a central computer. Software that is resident in volatile memory typically includes applications programs and/or operating parameters. Failure modes for digital and analog I/O points are found to vary among different DDC Systems.

2.6 SURGE PROTECTION AND OVERVOLTAGE PROTECTION

Digital logic systems are susceptible to interference from transients such as power line surges and lightning. Transient protection devices should be provided to minimize the damage which can be caused by tran--sients. Some DDC manufacturers indicated surge protection and overvoltage protection are provided on DDC equipment.

2.7 RELIABILITY/REPAIRS

Table 2-8 summarizes the system reliability and mean time to repair the central computer and DDC system panels. There is a large variation in these time factors among the manufacturers surveyed. According to the data provided, the mean time between DDC equipment failures tends to be greater than the central computer and the mean time to repair is shorter.

Most manufacturers indicated CPU, I/O, power supply, and memory boards can be replaced in the field and spare parts can be stored on site.

2.8 PRICING

Most manufacturers were able to provide cost estimates for standard DDC equipment, but indicated installation costs are site specific. Only a couple of manufacturers provided cost estimates for individual analog and digital points.

The cost differential between DDC systems and conventional systems with pneumatic control varies according to the project application software requirements and the manufacturer. Two manufacturers indicated there was no significant cost differential. Three manufacturers indicated DDC systems are likely to cost more than systems with pneumatic controls. One manufacturer indicated the relative cost of DDC equipment is dependent on the number of energy management programs required at the installation. According to this manufacturer, DDC systems costs are comparable to conventional pneumatic control systems if the installation requires at

Application software contains the instructions for controlling equipment in accordance with predetermined control strategies. As Table 2-6 indicates, most DDC systems are capable of performing most EMCS application programs. Programming languages are used to develop software and modify application software required by sequences of operation which are job specific. There is no standard programming language for DDC systems. The most common "generic" software language for programming DDC systems is "BASIC" or a modified form of BASIC. Some manufacturers have developed their own proprietary software.

Changes to DDC application software are generally accomplished through a local programming panel or through a portable terminal such as a portable printer or CRT/keyboard unit. DDC systems connected to a central computer can be reprogrammed by downloading programs from the central to the DDC panel. Changes to programs at the local DDC panel can also be uploaded to the central computer. Access to software modifications are limited by password protection.

Communications protocol is required for the DDC system to respond to central computer commands and to transmit information back to the central computer either through a dial-up modem or twisted pair. In most cases, communications protocol is proprietary. As a result, facilities with DDC systems and EMCS from different manufacturers have problems interfacing the DDC systems with a EMCS central computer. Some DDC system manufacturers have indicated communication is feasible only if the DDC system communications protocol is available for use from the central computer manufacturers. Most DDC and EMCS manufacturers stated that they are unwilling to permit the release of protocol to third parties, even with non-disclosure agreements.

Diagnostic software is used to identify and locate DDC system malfunctions. In some systems, diagnostics can be performed from either a central computer or from equipment built into the DDC. Some manufactuers also use portable diagnostic devices (refer to Table 2-3).

2.5 POWER FAILURE

In the event of power failure, all DDC systems have battery back-up capability for the real time clock and for volatile memory (RAM). Battery back-up capability varies from 8 hours to 30 days, depending on the system. (Refer to Table 2-7 for the summary of power failure back-up specifications).

In the event of power failure, DDC systems have battery back-up capability for the real time clock and for volatile memory (RAM). Battery back-up capability typically varies from 8 hours to 30 days, depending on the system. Software that is resident in non-volatile memory is <u>not</u> lost

2.3 DATA TRANSMISSION WITH CENTRAL COMPUTERS (EMCS)

The transmission media most frequently used by DDC systems for reporting to central computers of Energy Monitoring and Control Systems (EMCS) are twisted pair, dedicated telephone lines, dial up telephone lines and fiber optics. Transmission baud rates range from 300 to 9,600 baud, depending on the type and quality of transmission media used. Most manufacturers can connect at least eight DDC systems to each 1,200 baud transmission line (refer to Table 2-4). DDC response time to queries from a central computer of an EMCS varies from fractions of a second to several seconds, depending on the manufacturer and the type of information requested. For example, one manufacturer indicated the response time for an alarm is faster than the response time for data collection.

2.4 SOFTWARE

The basic types of software in DDC systems include:

- Operating software
- EMCS application software
- Programming language(s) for algorithmic control sequences
- Communications protocol
- Diagnostics

Operating software controls the operation of DDC system computer. Typical operating software functions include loading and executing progams, allocating storage for data and programs, and handling errors. In most DDC systems, the operating software is in non-volatile memory. Consequently, in the event of power failure and loss of battery backup, the operating software is not lost. In all but one case, the DDC system can be started up as a stand-alone unit. Most systems can also be started up from a EMCS central computer (refer to Table 2-5).

English words are more likely to be used at the central computer than at the DDC terminal, although the majority of the systems use english words for both. DDC units that don't use english words will frequently use key words or alphanumeric codes. In most cases, point status, parameters values, change of state and equipment failure data can be displayed at the DDC unit via a built-in panel. For DDC systems interfaced with the central computer, this data is also displayed at the central computer (refer to Table 2-5).

Most systems provide protection against unauthorized access to the data base and several levels of access into the DDC system (refer to Table 2-5).

CHAPTER 2

DDC STATE-OF-THE-ART TECHNOLOGY

2.1 GENERAL

This chapter summarizes the types of DDC hardware and software that are commercially available today. This information is primarily based on DDC manufacturers' literature and on a questionnaire developed by Kling-Lindquist and completed by DDC manufacturers within the past six months (see Appendix D for a sample questionnaire). Additional information is derived from technical publications (refer to Appendix C for a bibliography).

2.2 DDC SYSTEM HARDWARE CONFIGURATION

Most DDC systems can function as stand-alone systems or can interface with a central computer as part of central computer system such as Energy Monitoring and Control Systems (EMCS). DDC systems which interface with a central computer require communications protocol that is compatible with the central computer. Table 2-1 indicates which systems can communicate with a central computer and which systems may include a central computer as a part of total system configuration.

Table 2-1 also shows the total number of analog and digital I/O points and pulse accumulators available to typical DDC units, the number of control loops, and the number of I/O points per control loop. The smaller DDC systems typically have 32 to 64 I/O points and can handle 6 to 30 control loops. The number of I/O points for larger DDC systems can range from 100 to 500 points, depending on the manufacturer. Larger systems also have a large variation in the number of control loops.

Table 2-2 summarizes the variations in DDC system memory capacities among various manufacturers. In most systems, operating system programs are in nonvolatile memory, while default parameters and applications programs are in volatile memory. System memory is typically sized to meet the maximum number of control loops, and is job specific.

Hardware features common to all DDC systems include a real time clock, power failure/auto restart, and communications interface. The most common communications interface is RS232C. DDC systems typically use 8 or 16 bit microprocessors. Most DDC systems have at least two peripheral ports, a built-in diagnostic programming panel and capability for local display and control. Systems without built-in programming and diagnostic panels generally use portable terminals for diagnostics and programming. Hardware features of DDC systems are summarized in Table 2-3.

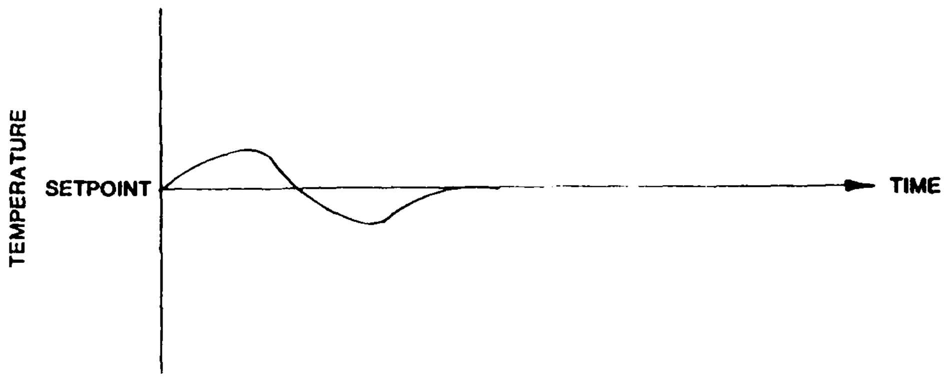

FIGURE 1 - 5: PROPORTIONAL INTEGRAL DERIVATIVE CONTROL

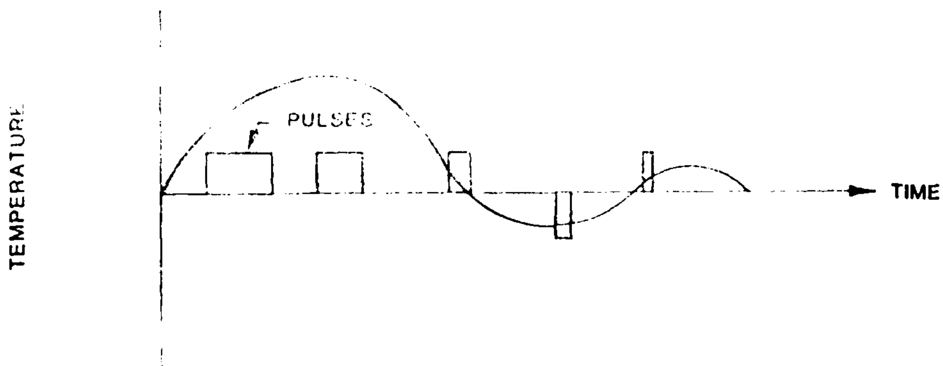

FIGURE 1 - 6: PULSE WIDTH MODULATION

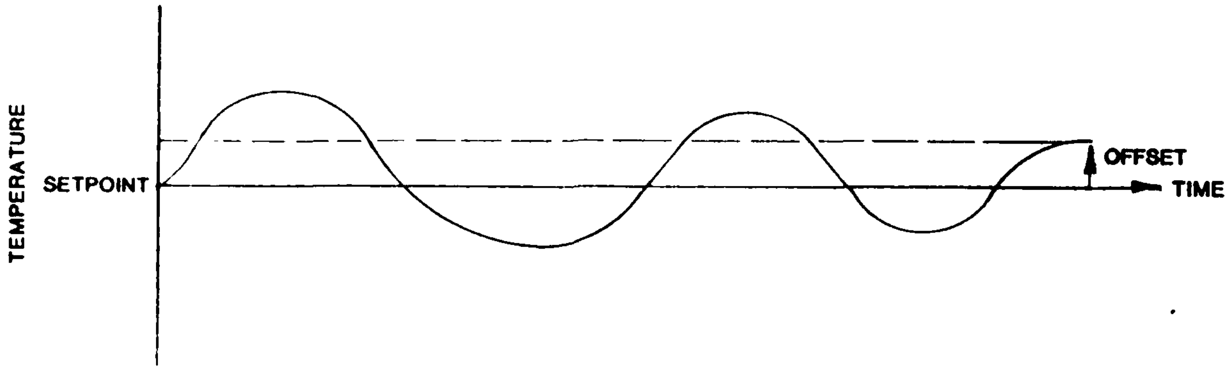

FIGURE 1 - 3: PROPORTIONAL CONTROL

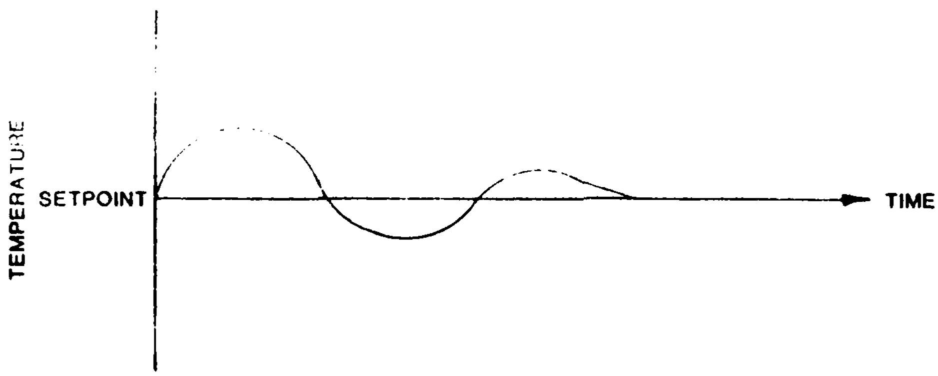

FIGURE 1 - 4: PROPORTIONAL INTEGRAL CONTROL

Methods of control associated wi ' the use of DDC systems include:

- Proportional control
- Proportional/Integral control (PI)
- Proportional/Integral/Derivative Control (PID)
- Pulse width modulation

Proportional Control is a control technique that assumes a specific position for each change in a measured variable (see Figure 1-3). Proportional control is the most common method of analog control in facilities where control point offsets can be tolerated. This method of control has the greatest probability of error in comparison with PI and PID due to the oscillation and offset that are characteristic of proportional control .

Proportional/Integral Control (PI) is a control technique which integrates the control point values over time to minimize the number of oscillations as it approaches the setpoint (see Figure 1-4). This method of control has a greater probability of error than PID control PI control offset is used in control of processes with fast response times.

Proportional/Integral/Derivative Control (PID) is a control technique which resets the proportional and integral correction signals based on the rate of change of the control point from the setpoint (see Figure 1-5). By using three mode control, PID eliminates hunting and offset when properly tuned PID is used in processes with slow response times.

Pulse-width Modulation is a method of controlling a modulating device by using "On/Off" signals that vary with the duration of the signal and with the duration between signals. Decreasing pulse widths are used as the setpoint is approached (see Figure 1-6).

The computer-based DDC System contains the necessary software to perform the following types of functions:

- Computer System operation
- Monitoring of Inputs and Outputs
- Reporting Function (alarm, status, logging)
- Application software to implement predetermined control strategies

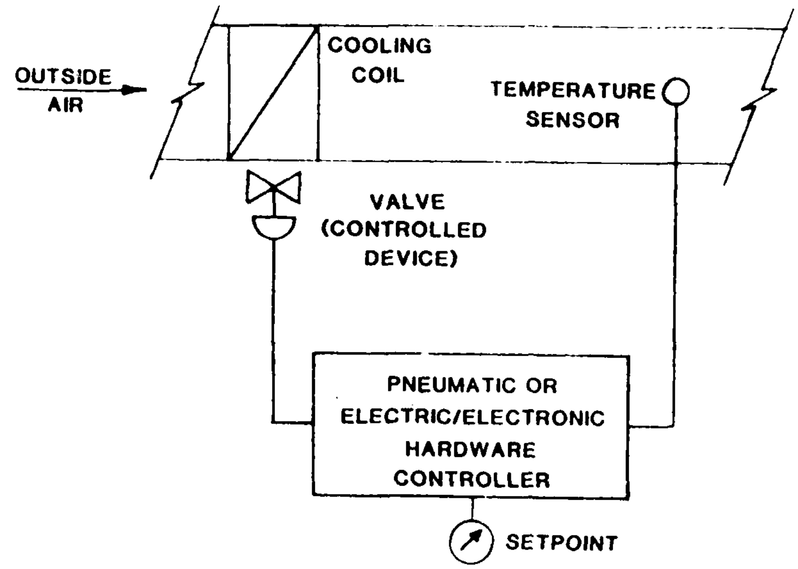

FIGURE 1 - 1: CONVENTIONAL CLOSED LOOP SYSTEM

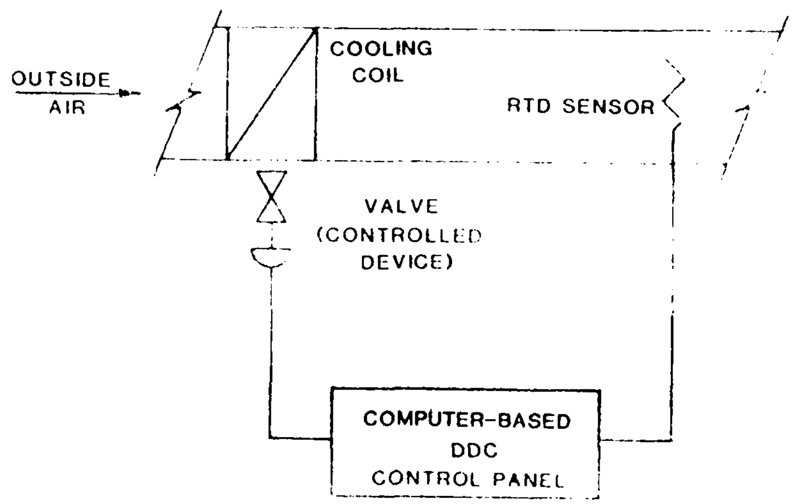

FIGURE 1 - 2: DIRECT DIGITAL CONTROL LOOP

TABLE 2-5
DDC SYSTEM SOFTWARE
SUMMARY OF QUESTIONNAIRE RESPONSES

		DDC START-UP:		ACCESS	ENGLISH WORDS:		.......DATA DISPLAYED AT DDC.......				DATA DISPLAY AT CENTRAL COMPUTER:				......CONTROL TECHNIQUES........			....ANALOG OUTPUT...	
	MANUFACTURER	FROM CENTRAL	STAND ALONE	PROTECT	AT CENTRAL COMPUTER	AT DDC	PT STATUS	PARM VALUE	CHG OF STATE	EQUIP FAIL	PT STATUS	PARM VALUE	CHG OF STATE	EQUIP FAIL	PROPORTIONAL CONTROL	PROPOR./ INTEGRAL CONTROL	PID CONTROL	PULSE WIDTH MODUL.	PROPORT. ELECTRONIC
1	ANDOVER	YES	YES	3 LEVELS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
2	ANDERSON CORNELIUS	YES	YES	AT LEAST 1 LEVEL	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
3	ATLANTIC ENERGY	NO	YES	3 LEVELS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
4	CLIMATRON	YES	YES	AT LEAST 1 LEVEL	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
5	COMPUTER SCIENCES	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
6	ENERSIST	NO	YES	1 LEVEL	N/A	YES	YES	YES	NOT STD	YES	YES	YES	NOT STD	YES	YES	YES	YES	YES	YES
7	HONEYWELL	YES	YES	3 LEVELS	OPTIONAL	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES		YES
8	JOHNSON CONTROLS	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
9	RAYTHEON	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES		
10	TOUR AND ANDERSON	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
11	COMPANY A	NO	YES	7 LEVELS	N/A	YES	YES	YES	YES	YES.........NO HOST COMPUTER.........					YES	YES	YES	NO	
12	COMPANY B	YES	YES	3 LEVELS	YES	NO	YES	YES	YES	YES	YES	YES	YES	YES			YES	YES	
13	COMPANY C	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES		

TABLE 2-6
DDC APPLICATION SOFTWARE
SUMMARY OF QUESTIONNAIRE RESPONSES

	MANUFACTURER	START/STOP	OPT. START/STOP	DUTY CYCLING	DEMAND LIMIT	DAY/NIGHT SETBACK	ECONOMIZER	ENTHALPY	VENT/RECIR	HOT/COLD DECK	REHEAT COIL RESET	BOILER SELECT	HW OA RESET	CHILLER SELECT	CHILL WATER RESET	CONDENS WATER RESET	CHILL. DEMAND	LIGHT CONTROL	ALGORITHMIC CONTROL SEQUENCES	PROGRAMMING LANGUAGE
1	ANDOVER	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	PROPRIETARY
2	ANDERSON CORNELIUS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	PAL (PROCEDURAL APPLICATION LANGUAGE)
3	ATLANTIC ENERGY	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
4	CLIMATRON	YES	YES	YES	YES	YES	YES	YES	YES	YES	*	*	*	YES	YES	YES	YES	YES	YES	BASIC
5	COMPUTER SCIENCES	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES	NO	YES	NO	YES	YES	YES	YES	YES	ILTRAN
6	ENERSIST	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	NO	YES	YES	YES	LADDER DIAGRAMS
7	HONEYWELL	YES	YES	YES	YES	YES	YES	YES	YES	YES.............CUSTOM DESIGNED..................									YES	RACL (PROPRIETARY)
8	JOHNSON CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	CAL1
9	RAYTHEON	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES		YES	FORTRAN, BASIC, FORCE
10	TOUR AND ANDERSON	YES	YES	YES	*	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	FORTRAN, BASIC, IPCC (PROPRIETARY)
11	COMPANY A	YES	YES	YES	YES	YES	NO	*	YES	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	
12	COMPANY B	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES		YES	
13	COMPANY C	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	NO	NO	NO	YES	YES	NO		YES	DEC OPER. SYSTEM LANG., PPCL (PROPRIETARY)

* AVAILABLE BY 1985

TABLE 2-7
DDC POWER FAILURE/AUTO RESTART
SUMMARY OF QUESTIONNAIRE RESPONSES

	MANUFACTURER	BATTERY BACKUP: CLOCK	BATTERY BACKUP: RAM	IF NO MEMORY BACKUP IS AVAILABLE: OPER. SYSTEM LOST?	IF NO MEMORY BACKUP IS AVAILABLE: APPL. PROG LOST?	IF NO MEMORY BACKUP IS AVAILABLE: OPER. PARM LOST?	AUTO RESTART WHEN POWER IS RESTORED?	DIGITAL OUTPUT FAILURE MODES: ON CPU	DIGITAL OUTPUT FAILURE MODES: OFF I/O	DIGITAL OUTPUT FAILURE MODES: LAST COMMAND	ANALOG OUTPUT FAILURE MODES: HIGH VALUE	ANALOG OUTPUT FAILURE MODES: LOW VALUE	ANALOG OUTPUT FAILURE MODES: MID RANGE	ANALOG OUTPUT FAILURE MODES: LAST COMMAND
1	ANDOVER	3 -48 HRS	3 -48 HRS	NO	YES	YES	YES	YES	YES	YES	NO	NO	NO	YES
2	ANDERSON CORNELIUS	1 YR	12 HRS	NO	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES
3	ATLANTIC ENERGY	3 DAYS	3 DAYS	NO	YES	YES	YES	YES	YES					
4	CLIMATRON	30 DAYS	30 DAYS	NO	NO	DEFAULTS TO PROM	YES			YES				YES
5	COMPUTER SCIENCES	8 HRS	8 HRS	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES
6	ENERGIST	31 DAYS		NO	YES	YES	YES	....DEPENDS ON APPLICATION....						YES
7	HONEYWELL	72 HRS	72 HRS	NO	YES	YES	YES		YES			YES		
8	JOHNSON CONTROLS	72 HRS	72 HRS	NO	YES	YES	YES			YES				YES
9	RAYTHEON	YES		NO	YES	YES	YES		YES			YES		
10	TOUR AND ANDERSON	7 DAYS-2 MO 5 YRS		NO	NO	YES	YES YES	.........OPTIONAL.......... ....OPTIONAL..........			.........OPTIONAL.......... ....OPTIONAL..........			
11	COMPANY A	30 DAYS		NO	NO	NO	YES	NO	NO	YES	NO	NO	NO	YES
12	COMPANY B	30 DAYS		NO	NO	NO	YES	YES	YES	YES				YES
13	COMPANY C	8 HRS 4-48 HRS		NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	

TABLE 2-8
DDC SYSTEM RELIABILITY/REPAIR
SUMMARY OF QUESTIONNAIRE RESPONSES

	MANUFACTURER	MEAN TIME BETWEEN FAILURES		MEAN TIME TO REPAIR		BOARDS REPLACED IN FIELD				SPARE PARTS STORED ON SITE				TRAINING
		CENTRAL COMPUTER	DDC	CENTRAL COMPUTER	DDC	TRANSMISS CPU	RESPONSE I/O	POWER SUPPLY	MEMORY	CPU	ELECTRONIC I/O	POWER SUPPLY	MEMORY	
1	ANDOVER	Nav	25000 HRS	Nav	24 HRS	YES	YES	YES	YES	YES	YES	NO	YES	YES
2	ANDERSON CORNELIUS	8000 HRS	8000 HRS	60 MIN	60 MIN	YES	YES	YES	YES	YES	YES	YES	YES	YES - 40 HRS
3	ATLANTIC ENERGY		3% in 4 YRS		1 DAY	YES	YES	YES	YES		YES		YES	YES - 1 TO 2 DAYS
4	CLIMATRON	4000 HRS	4200 HRS	48 HRS	48 HRS	YES	YES	YES	YES	YES	YES	YES	YES	YES
5	COMPUTER SCIENCES	5000 HRS	30000 HRS	4 HRS	0.5 HRS									YES
6	ENERGIST													YES
7	HONEYWELL	UNKNOWN	UNKNOWN	UNKNOWN	0.5-1 HR	YES	YES	YES	YES	YES	YES	YES	YES	YES - 2 TO 3 WKS
8	JOHNSON CONTROLS	7000 HRS	17000 HRS	5 HRS	1.5 HRS	YES	YES	YES	YES	YES	YES	YES	YES	YES
9	RAYTHEON					YES	YES	YES	YES	YES	YES	YES	YES	YES
10	TOUR AND ANDERSON					YES	YES	YES	YES	YES	YES	YES	YES	YES
11	COMPANY A	10000 HRS	15000 HRS	2 HRS	2 HRS	YES	YES	YES	YES	YES	YES	YES	YES	YES - 1 WEEK
12	COMPANY B	70 MONTHS	60 MONTHS	10 MIN	10 MIN	YES	YES	YES	YES	YES	YES	YES	YES	YES - VIA TELEPHONE
13	COMPANY C	1 - 3 YRS	3 YRS	UNKNOWN	30 MIN	YES	YES	YES	YES		YES			YES

TABLE 2-9
DDC SYSTEM COSTS
SUMMARY OF QUESTIONNAIRE RESPONSES

MANUFACTURER	MODEL TYPE	EQUIPMENT COSTS FOR STANDARD UNIT: STAND-ALONE NO I/O	STAND-ALONE WITH I/O	DIGITAL OUTPUT	DIGITAL INPUT	ANALOG OUTPUT	ANALOG INPUT	PULSE ACCUMUL.	PNEUMATIC/DDC PRICE DIFFERENTIAL
1 ANDOVER	AC256 AC8		10000 3600	..................NO ADDITIONAL CHARGE............ ....NO ADDITIONAL CHARGE............					DDC IS COST COMPETITIVE FOR CENTRAL PLANT AND AHU. PNEUMATICS IS 20 - 40% LESS FOR VAV TERMINAL UNITS.
2 ANDERSON CORNELIUS	MCU-500 MCU-250 MCU-260								
3 ATLANTIC ENERGY	AET 616/32	4500	4500						NO DIFFERENCE, BASED ON LAST 10 PROJECTS BID.
4 CLIMATRON	4000 2100	5000 NA	8000 2400-6400						
5 COMPUTER SCIENCES	INFOSCAN	2000		110					DEPENDS ON COMPLEXITY OF SYSTEM.
6 ENERGIST			5500 (60 PTS)						DDC IS 10% HIGHER.
7 HONEYWELL	R7510		9000 (96 PTS)	DEPENDS ON TYPE OF SENSOR					DDC IS 20-30% HIGHER WITH NO ENERGY MANAGEMENT PROGRAM. DDC IS COST COMPETITIVE FOR A FEW ENERGY MGT. PROGRAMS. DDC COSTS LESS IF PROJECT HAS A LOT OF ENERGY MGT. PROGRAM
8 JOHNSON CONTROLS	DSC-8500		10000 INSTALLED						
9 RAYTHEON	FID/LDM FID/MCI								
10 TOUR AND ANDERSON	V2 V3A V3D	3000 3500 3500	4000 4500 4500	7 7	7 7	100 100			DDC IS 20-30% HIGHER.
11 COMPANY A		75000	25000 FOR 32 AI, 16 AO, 64 DI, 64 DO						
12 COMPANY B									
13 COMPANY C		2000-3000	2500-4000						GENERALLY, DDC IS COST COMPETITIVE. IN THE WORST CASE, DDC IS 10-15% MORE COSTLY.

CHAPTER 3

CURRENT DDC DESIGN AND INSTALLATION PRACTICES

3.1 GENERAL

This chapter describes the codes and standards currently being used for DDC system design and installation, and the estimated lead time and special requirements for shop drawings and installation. This information is based on data received from DDC equipment manufacturers, (as summarized in Table 3-1) and from recent engineering experience with DDC installations.

3.2 CODES AND STANDARDS

The National Electrical Code is the most commonly used code in the design and installation of DDC systems. Most of the wiring required for DDC systems is low voltage (48 volts or lower). Sensor and control wiring does not need to be installed in conduit except as required for physical protection of the wiring.

3.3 CONTRACT DOCUMENTS

The contract documents for a DDC system describe the type of system to be installed, the layout of the DDC equipment, controls and sensors to be used by the DDC, and software required for the project. The procedures developed for EMCS contract documentation are typically used by the engineer for DDC system projects.

3.4 SHOP DRAWINGS

Shop drawings contain the list of equipment, sequences of operation, and materials required for DDC system installation. On these drawings, the installing contractor indicates the system configuration, proposed layout and installation methods. Shop drawings indicate wiring methods and routing. Requirements for DDC shop drawings are the same as those for conventional control systems. It is particularly important that the contractor provide software descriptions and logic diagrams to ensure that the DDC can perform the control functions specified for the job.

In the questionnaire, DDC manufacturers were asked to estimate the lead time to complete shop drawings for a stand-alone DDC project with approximately 100 points. The estimated time range was two weeks to two months, depending on the system (see Table 3-1). The preparation of shop drawings

for a single DDC system panel is estimated to require one month. The lead time for shop drawing approval of DDC systems is the same as for shop drawing approval of conventional pneumatic systems.

Depending on the type of project, lead time for DDC drawing submittal may be one half of time required for conventional system drawing submittal.

3.5 INSTALLATION

For a 100 point DDC stand-alone system, most DDC manufacturers estimated installation time after shop drawing approval would require one to three months. Equipment and software should be immediately available for installation after DDC sensor and controls are installed. Software that is job specific is developed after shop drawing approval using the available high level language software.

DDC systems can be interfaced with electric and pneumatic controls with the use of transducer devices. Electronic interface between DDC equipment and an EMCS or other DDC equipment of a different manufacturer can not be readily accomplished without the development of special software. Unless communications protocol is provided by the DDC system manufacturer, interface with EMCS and DDC or between DDC systems of different manufacturers may be impossible.

Environmental requirements for various types of DDC systems are shown in Table 3-1. Most manufacturers require a dry bulb temperature range of 32°F to 120°F and a relative humidity range of 0 to 95 percent.

The power supply requirements for most DDC systems is 120 volts ± 15 percent.

TABLE 3-[illegible]
DDC SYSTEM DESIGN AND INSTALLATION GUIDELINES
SUMMARY OF QUESTIONNAIRE RESPONSES

	MANUFACTURER		ESTIMATED LEAD TIME TO COMPLETE [illegible]			CODES AND INDUSTRY STANDARDS						FOR DDC INSTALLATION:			ENVIRONMENTAL CONDITIONS				AC POWER SUPPLY
			[illegible]	INITIAL	CHECKOUT	CTM SURGE	DTM OVERVOLTAGE	POWER LINE SURGE	POWER LINE OVERVOLTAGE	I/O SURGE	I/O OVERVOLT	NEC	BOCA	NFPA	MIN DRY BULB	MAX DRY BULB	MIN % RH	MAX % RH	
1	ANDOVER	[illegible]	[illegible] DAYS	[illegible] MONTHS	1 MONTH			YES	YES	YES	YES				32	120	0	95	117 +-20%
		[illegible]	[illegible]	[illegible] DAYS	1 MONTH			YES	YES	YES	YES				32	120	0	95	117 +-20%
2	ANDERSON CORNELIUS		4 WKS	4 WKS	1 WK	SURGE AND OVERVOLTAGE PROTECT DESIGNED INTO TRANSMISSION, I/O AND POWER									32	122	10	95	120 +-40V
3	ATLANTIC ENERGY		[illegible] WKS	[illegible] DAYS	2 DAYS	OVC	OVC	IN LINE FILTER	CONSTANT VOLTAGE POWER SUPPLY	OVC	OVC	YES			20	125	5	95	120 +-15%
4	CLIMATRON		[illegible] WK INC SUPPLY	4 WKS	0.5 WKS	OPTICAL ISOLATION	FUSED		FUSED	SNUB CIRCUIT	FUSED	YES	NO	NO	-40	160	2	100	120 VAC
5	COMPUTER SCIENCES		60 DAYS	90 DAYS	15 DAYS	IEEE 472	FUSE	IEEE 587	FUSE	IEEE 472	FUSE	YES	YES		32	122	0	95	120 +-15V
6	ENERSIST														40	110			110 +-5V
7	HONEYWELL		3 WKS	4 WKS	16 MANHRS	OPTICAL ISOLATION				STATIC PROTECTION		YES	YES	YES	32	122	0	95	120 +10%, -15%
8	JOHNSON CONTROLS		60 DAYS	60 DAYS	90 DAYS			UL & CSA	UL & CSA	NEC		YES			32	125	10	90	120 +10% -15%
9	RAYTHEON		1 MANMONTH	[illegible] MANWKS	1 MANWEEK			IEEE 472	IEEE 472	IEEE 472	IEEE 472	YES	YES	YES	0	50	0	95	110 +-10%
10	TOUR AND ANDERSON		10-15 WORK DAYS	10-15 WORK DAYS	3 DAYS										32	104			
11	COMPANY A		STANDARD PROD.	6 MONTHS	6 MONTHS							YES	NO	YES		93	0	95	117 +-10V
12	COMPANY B		6 WKS	4 WKS	2 WEEKS							YES	YES	YES	-30	130	0	90	
13	COMPANY C		10-14 DAYS	.......DEPENDS ON SITE.....															120 +-15%

CHAPTER 4

CURRENT DDC TESTING PRACTICES

4.1 GENERAL

This Chapter describes the current practices for testing DDC hardware and software. Information is based on the questionnaire responses and engineering field experience.

4.2 HARDWARE

A 100 point stand-alone DDC panel takes from two days to two weeks for hardware checkout depending upon the manufacturer. Additional time is required for the sensors and control I/O checkout.

Hardware and software testing of DDC system prototypes is conducted in the Factory by the manufacturer. Factory tests should include surge protection and overvoltage protection tests, as well as lab testing of equipment for FCC-type acceptance of computer equipment. DDC equipment must be successfully tested prior to the delivery to the project site. In order to avoid costly delays in project completion, the DDC System to be installed should not require any new hardware or software development.

Calibration and adjustment of I/O is required only for analog points, and is performed by the contractor at the project site.

Diagnostics are conducted on DDC hardware using built-in devices or portable diagnostic devices, whichever is applicable to the type of DDC system.

4.3 SOFTWARE

No lead time is required to checkout the DDC operating system, since this software is inherent to the DDC system panel and is not job specific. Applications programs require from one week to six months for checkout, depending on the types of applications programs and the time of year the checkout occurs. For example, some of the applications programs may control the operation of seasonal equipment which is not in operation during the initial checkout period. Additional checkout tests are therefore required when this seasonal equipment is in operation. Typically, software testing of a 100 point system takes two weeks for checkout.

4.4 ACCEPTANCE TESTING

The complete DDC system is checked to verify system operation on a random basis required by the contract documents.

CHAPTER 5

CURRENT DDC MAINTENANCE PRACTICES

5.1 GENERAL

DDC systems are designed to be easily maintained by trained personnel. There are no moving parts which require calibration or adjustment, and most major DDC system panel circuit boards can be easily removed and replaced with spare boards to minimize down time.

5.2 EQUIPMENT

DDC system manufacturers indicated replaceable DDC boards include the central processing unit (CPU), memory, I/O boards, and power supply. Diagnostics can be performed by a built-in device or a portable diagnostic device. Modifications to application software can also be accomplished using built-in devices or a portable diagnostic device.

5.3 TRAINING/PERSONNEL

Most manufacturers provide short term (one day to two weeks) training for the Owner's employees in DDC diagnostics and repair. Additional training is required for employees who need to perform changes to the application software.

CHAPTER 6

FUTURE TRENDS

6.1 GENERAL

DDC systems are expected to play an increasing role in the commercial and industrial control industry as manufacturers continue to improve upon the technology and cost effectiveness of DDC system. Pneumatic/ electric/electronic systems will be replaced as the technology advances and the price of DDC systems decline.

6.2 HARDWARE

Current trends in DDC hardware development indicates DDC systems are becoming more powerful and more adaptable to variations in project requirements. A number of manufacturers use "off-the-shelf" microcomputers to communicate with the remote DDC system panels, download application programs, and perform diagnostics. This approach enables DDC manufacturers to use the state-of-the-art in microcomputer technology without investing considerable capital in a proprietary system. In addition, new development in microcomputer technology such as expanded memory can increase the power of the DDC system.

6.3 SOFTWARE

DDC software capabilities will also expand as more systems are installed and users find new applications for DDC control. Man-machine interfaces will become more user friendly. Prompting menus are expected to be more commonplace. This approach minimizes the training required for operators to become familiar with the system.

Modification of existing programs and new program development will take place more often in the field through the use of high-level user-friendly programs.

6.4 INSTALLATION

Current methods of DDC installation are not expected to change in the future. However, installation and checkout problems are expected to decline as more DDC systems are installed and more personnel become familiar with installation practices.

6.5 INTERFACE WITH EMCS

The use of DDC systems with larger centralized EMCS will become more commonplace with minimum interface problems if both DDC and EMCS are from the same manufacturer.

As long as manufacturers continue to design DDC systems with proprietary communications protocol, problems of interfacing DDC systems with EMCS from different manufacturers will continue.

6.6 DIAGNOSTICS

Diagnostics software is expected to be more user-friendly to minimize training required for operators to become familiar with diagnostic procedures and results. Menu-driven software in portable diagnostic systems is becoming a very popular technique for DDC diagnostics.

6.7 MAINTENANCE AND REPAIR

Maintenance procedures on DDC systems are not expected to change in the near future. System malfunctions generally require circuit board replacements, which can be accomplished with little training.

CHAPTER 7

RECOMMENDATIONS

7.1 GENERAL

It is recommended that the Government consider DDC installation on a case by case basis. The complexity of the project, the types of monitoring control systems (EMCS) currently installed at the site, and the expected support of the manufacturer all have a direct bearing on the decision to use DDC systems. The following recommendations are intended to be minimum requirements for DDC system hardware and software.

7.2 HARDWARE

DDC systems should be able to function as stand-alone systems with the capability of interfacing with another DDC or with a central computer of at least the same manufacturer.

The equipment should be able to operate in an unconditioned space with a temperature range from 32 to 120 degrees F, and a relative humidity ranging from 0 to 95 percent.

Power line surge protection should be provided so that the equipment can meet surge requirements of IEEE 587. Sensor and control wiring should be protected against surges induced on control and sensor wiring installed outdoors.

The DDC system must be provided sufficient memory for the operating system software and applications programs. Each DDC panel should have a real time clock with battery backup, a communications interface (preferably RS232C) and at least one peripheral port (for local display, printer, etc.). Battery back-up should also be provided for volatile memory. Portable or built-in equipment should be provided for programming and diagnostics.

7.3 COMMUNICATIONS PROTOCOL

A standard communications protocol must be developed for interfacing DDC systems with EMCS of different manufactuers. Requirements should be established for delivery of manufacturer proprietary data to the Government for its own use and for third party use (EMCS Manufacturer) for interface purposes.

Unless a standard communications protocol is developed by the DDC industry, the Government should consider the installation of DDC system of

only one manufacturer in any one Government installation. Use of a single manufacturer's equipment can facilitate DDC system interface with an EMCS when interface is required.

7.3 SOFTWARE

The stand-alone DDC panel should have automatic restart capabilities when power is restored after a power failure, and the duration of the failure is less than battery capacity.

The DDC panel should be provided with a high-level language (such as BASIC) for writing application programs. The man-machine interface software should have english words that allow technician level operators to use the system without extensive training. In order to protect against unauthorized access, the DDC panel should have at least one password protection level. At the minimum, the following data should be provided at the DDC panel:

- Point status
- Parameter values
- Change of state
- Equipment failure

The DDC panels should have the capability of performing proportional PI, and PID control. The DDC panels should be able to interface with digital I/O points and analog I/O points through a device similar to an alarm analog to transducer (i.e. pressure to current transducer). DDC panels should be able to perform the following EMCS applications programs either with standard software or with software that can be developed:

- Start/Stop
- Optimum Start/Stop
- Duty Cycling
- Demand Limit
- Day/Night Setback
- Economizer
- Enthalpy
- Ventilation/Recirculation
- Hot Deck/Cold Deck Temperature Reset
- Reheat Coil temperature Reset
- Lighting Control
- Algorithmic Control Sequences

Diagnostics software should be available to detect component failures, check errors, and check computer memory.

APPENDIX "C"

BIBLIOGRAPHY

Coad, William, EMCS and Digital Controllers, Heating/Piping/Air Conditioning, August 1983, (pp. 112-119).

Direct Digital Control: Next Generation for Building Automation, Specifying Engineer, August 1982, (pp. 66-70).

Distributed Processing and DDC Control: A Retrofit Application, ASHRAE Transactions 1980, Vol. 86, Part 1.

Dobrowolski, Mark, *Guide to Selecting Distributed Digital Control Systems*, In Tech, June 1981, (pp. 45-52).

Energy Users News, Articles on Direct Digital Control, 9/27/82 and 4/30/84.

Haines, Roger, Monitoring and Control Systems (Parts I - IX), Heating/Piping/Air Conditioning, August 1982 - April 1983.

The Impact of Microprocessors on Process Control, Computer Design April 21, 1983, (pp. 111-116)

Meinhold, Ted, Computerized Energy Management Systems, Plant Engineering, August 19, 1982, (pp 54-65).

U.S. Army Corps of Engineers, Huntsville, Alabama, Energy Monitoring and Control Systems, Guide Specifications for Energy Monitoring and Control Systems, Large System Configuration, May 1984.

RS-232 and RS 422: Technical specifications established by the Electronics Industries Association for interfacing modems with terminals or computers.

Selective Generation: Where the management of input/output is restricted to selected peripherals.

Sensors: Devices used to detect or measure physical phenomena.

Software: A term used to describe all programs whether in machine, assembly, or high-level language.

Stand-Alone: A term used to designate a device or system which can perform its function totally independent of any other device or system.

Supervisory Control: Separate (and usually remote) control and monitoring of local control loops. (See Direct Digital Control.)

Three Mode Control: Proportional integral derivative control.

True digital: A representation of any value by symetric digits, used to form fixed length words.

Volatile Memory: A semiconductor device in which the stored digital data is lost when power is removed.

Word: A set of binary bits handled by the computer as the primary unit of information.

Zone: An area composed of a building, a portion of a building, or a group of buildings affected by a single device or piece of equipment.

Process Control:	The collective functions performed by the equipment which is to control a variable.
Program:	A sequence of instructions causing the computer to perform a specified function.
Proportional:	A control technique that assumes there is a specific position for each change in a measured variable.
Proportional Integral:	A control technique which integrates the control plant reset values over time to minimize offset.
Proportional/Integral Derivative Control (PID)	A control technique which resets the proportional and integral correction signals based on the rate of the control point from setpoint.
Protocol:	A formal set of conventions governing the format and relative timing of message exchange between two terminals.
Random Access Memory (RAM):	Volatile semiconductor data storage device in device in which data may be stored or retrieved. Access time is effectively independent of data location.
ROM, PROM, EPROM, EEPROM:	Read-Only-Memory, Programmable ROM, Erasable PROM, Electronically Erasable PROM. All are non-volatile semiconductor memory.
Real Time:	A situation in which a computer monitors, evaluates, reaches decisions, and effects controls within the response time of the fastest phenomenon.
Real Time Clock (RTC):	A device which indicates actual time of day. The RTC may be updated by hardware or software.
Register:	A digital device capable of retaining information.
Reinitialization:	Refer to initialization.
Resistance Temperature Detector (RTD):	A device where resistance changes linear as a function of temperature.

Microprocessor: A central processing unit fabricated as one integrated circuit.

Mnemonic: A symbolic representation or abbreviation to help operators remember and understand.

MODEM: An acronym for MOdulator/DEModulater. A hardware device used for changing digital information to and from an analog form to allow transmission over voice grade circuits.

Non-Volatile Memory: Memory which retains information in the absence of applied power (i.e.; magnetic core, ROM, and PROM).

Normal Mode Operation: Equipment operating and performing its assigned tasks.

Open Loop Control: A control method where the computer can send commands to control points, but no information can be received from the field.

Operating System: A complex software system which manages the computer and its components and allows for human interaction.

Optical Isolation: Electrical isolation of a portion of an electronic circuit by using optical semiconductors and modulated light to carry the signal.

Parameter: A variable that is given a constant value for a specific purpose or process.

Parity: A checking code within a binary word used to help identify errors.

PASCAL: A "structured programming" high level computer language.

Peripheral Equipment: Equipment used for man-machine communications and further support of a processor.

Point: Individual connected monitor or control devices (i.e., relay, temperature sensor).

Input/Output Bus: The connection through which data is transmitted and received from peripheral devices interacting with the processor.

Input/Output (I/O) Device: Digital hardware that transmits or receives data.

Interactive: Functions performed by an operator with the machine prompting or otherwise assisting these endeavors, while continuing to perform all other tasks as scheduled.

Interrupt: An external or internal signal requesting that current operations be suspended to perform more important tasks.

Line Conditioning: Electronic modification of the characteristic response of a line to meet certain standards. The characteristics include frequency response, signal levels, noise suppression impedance, and time delay.

Loader: A program used to prepare the computer and store other programs into memory locations in preparation for machine execution.

Local Loop Control: The controls for any system or subsystem which existed prior to the installation of an EMCS and which will continue to function when the EMCS is non-operative.

Memory: Any device that can store logic 1 and logic 0 bits in such a manner that a single bit or group of bits can be accessed and retrieved.

Memory Address: A binary number that specifies the precise memory location of a stored word.

Memory Modules: Increments of memory, usually 4K, 8K, 16K, etc. words in length.

Microcomputer: A computer system based on a microprocessor and containing all the memory and interface hardware necessary to perform calculations and specified transformations.

Disk Storage: A bulk storage, random access device for storing digital information. Usually constructed of a thin rotating circular plate having a magnetizable coating, a read/write head and associated control equipment.

Distributed Processing System: A system of multiple processors each performing its own task, yet working together as a complete system under the supervision of a central computer, to perform multiple associated tasks.

Download: The transfer of digital data or programs from a central computer to another data processing system such as a microcomputer.

Duplex: A method of operation of a communications line in which each terminal can simultaneously transmit and receive.

EMCS: Energy Monitoring and Control System.

Firmware: A procedure for accomplishing arithmetic operations where the instruction set is resident in ROM or PROM.

FORTRAN: An acronym for FORmula TRANslation. A highlevel, English-like programming language used for technical applications.

Function Keys: Keys which, when depressed, send more than one character and are interpreted by the computer as a specific command.

Half duplex: A method of operation of a communications line in which each terminal can transmit and receive, but not simultaneously.

Hardware: Equipment such as a CPU, memory, peripherals, sensors, and relays.

Initialization: (of the System) The process of loading the operating system with the computer. Initialization is required to start normal operation of the computer after the computer has been out of service.

Control Sequence:	Equipment operating order established upon a correlated set of data environment conditions.
Control Loop:	The path followed by control signals to perform a task and by feedback signals to indicate the response to control.
Data Communications Equipment:	A device for transmitting digital information to and from any other system.
Data Transmission Media (DTM):	Transmission equipment including cables and interface modules (excluding MODEMs) permitting transmission of digital and analog information.
Debug:	The procedure of running a program to detect and correct errors in a program.
Deck:	In HVAC terminology, the air discharge of the hot or cold coil in a duct serving a conditioned space.
Demand:	The term used to describe the maximum rate of use of electrical energy averaged over a specific interval of time and usually expressed in kilowatts.
Diagnostic Program:	Machine-executable instructions used to detect and isolate malfunctions.
Digital Signals:	A discontinuous signal, the various states of which are descrete intervals apart. In radix 2 the signal is either on or off (zero or one) and is referred to as binary.
Direct Digital Control (DDC):	Sensing and control of processes directly with digital control electronics.
Digital to Analog (D/A) Converter:	A hardware device which converts a digital signal into a voltage or current proportional to the digital input.

Bus:	A circuit path (or parallel paths) over which data instructions are transferred to all points in the computer system. Computers have several separate busses: the data, address, and control busses are those of greatest importance.
Byte:	Eight bits.
Cathode Ray Tube (CRT):	An electron beam tube in which the beam is focused to a small cross section on a luminescent screen and varied in position and intensity to produce a visible pattern.
Central Processing Unit (CPU):	The portion of a computer that performs the interpretation and execution of instructions. It does not include memory or I/O.
Character:	One of a set of elementary symbols which normally include both alpha and numeric codes plus punctuation marks and any other symbol which may be read, stored, or written.
Clock:	A device or a part of a device that generates all the timing pulses for the coordination of a digital system. System clocks usually generate two or more clock phases. Each phase is a separate, square wave pulse train output.
Closed Loop Control:	A control method where a sensor continuously feeds information about a variable back to the controller.
Communications Interface Protocol:	A formal set of conventions governing the format and relative timing of message exchange between two terminals.
Contract Documents:	Developed by the Government to describe the type of DDC to be installed. Used by the contractor to describe the scope of work.
Controls:	Devices which govern the performance of a system.
Control Point Adjustment (CPA):	The procedure of changing the operating point of a local loop controller from a remote location.

APPENDIX "B"

DEFINITIONS

Algorithm:	A set of well defined rules or procedures for solving a problem or providing an output from a specific set of inputs.
Analog:	A continuously varying signal value temperature, current pressure, etc.)
Analog to Digital Converter:	A circuit or device whose input is information in analog form and whose output is the same information in digital form.
Applications Programs	Set of instructions for controlling equipment based on a set of conditions that may vary over time. For example, the start/stop applications program starts up and/or shuts down equipment according to the time of day and the day of the week.
ASCII:	American Standard Code for Information Interchange. An 8-bit coded character set to be used for the general interchange of data among information processing systems, communications systems, process control systems, and associated equipment. Various character/graphic subsets are discussed in FIPS PUB 15.
BASIC:	An acronym for Beginners All-Purpose Symbolic Instruction Code, a highlevel, English-like programming language used for general applications.
Baud:	A unit of signalling speed equal to the number of discrete conditions, or signal events, per second.
Bit:	An acronym for binary digit. The smallest unit of information which can be represented. A bit may be in one of two states, represented by the binary digits 0 and 1.

RTC	Real time clock
RTD	Resistance temperature detector
S/S	Start/stop

EMI	Electromagnetic interference
EEPROM	Electronically erasable PROM
EPROM	Erasable PROM
FAR	Federal Acquisition Regulations
HVAC	Heating, ventilating, and air conditioning
I/O	Input/output
K	Thousand
kHz	Kilohertz
kW	Kilowatt
kWh	Kilowatt-hour
LAN	Local Area Networks
Mb	Megabyte
MBtu	Btu (millions)
MODEM	Modulator/demodulator
OA	Outside air
PROM	Programmable ROM
PI	Proportional integral
PID	Proportional integral derivative
psig	Pounds per square inch, gauge
PT	Potential transformer
RAM	Random access memory
RF	Radio frequency
RH	Relative humidity
ROM	Read only memory

APPENDIX "A"

ABBREVIATIONS

A/D	Analog to digital
AHU	Air handling unit
AI	Analog input
AO	Analog output
ASCII	American Standard Code For Information Interchange
ATC	Automatic temperature control
bps	Bits per second
Btu	British thermal unit
CPA	Control point adjustment
cps	Characters per second
CPU	Central processing unit
CRT	Cathode ray tube
CT	Current transformer
D/A	Digital to analog
dc	Direct current
DDC	Direct digital control
DE	Data environment
DI	Digital input
DO	Digital output
DTM	Data transmission media
EMCS	Energy monitoring and control systems

7.10 GOVERNMENT ACCEPTANCE TESTING

Performance verification and endurance tests should be conducted on DDC systems prior to Government acceptance. A number of the tests developed for EMCS can apply to DDC systems.

7.11 MAINTENANCE AND OPERATION

Policies should be be established for maintaining and operating DDC systems. If a Government installation contains DDC systems from more than one manufacturer, Government facility personnel must be trained to handle the variations in equipment maintenance and operation procedures.

7.5 SPECIFICATIONS

It is recommended that a Corps of Engineer Guide Specification be developed for DDC systems.

7.6 CONTRACT DOCUMENT PREPARATION

The procedures developed for EMCS contract documentation should be used in DDC system design. Minimum design and documentation requirements for Government construction contracts should be established. It is particularly important that there be full documentation on the location and installation of sensors and controls used by the DDC system, and full documentation of software requirements.

Detailed sequences of operation should be provided so that the contractor can program the DDC system to meet the needs of the project.

Requirements must be established for contractor furnished data that the Government will need after the DDC system is installed. By establishing these requirements, the Government can avoid similar problems that have resulted in expanding EMCS.

7.7 SHOP DRAWINGS

Shop drawings for DDC systems should be prepared under the same requirements as those for EMCS. The contractor must indicate system configuration, proposed layout and installation. Shop drawings should detail sensor and control wiring and routing. It is recommended that the contractor provide detailed software descriptions, and logic diagrams, and sequence of operation to ensure that the software meets contract requirements.

7.8 INSTALLATION

DDC system installation should be conducted under the same guidelines as those established for EMCS installation.

7.9 CONTRACTOR TESTING

It is recommended that the contractor conduct field tests to verify that sensors and controls are properly wired, DDC equipment is properly installed and grounded, overvoltage and surge protection devices are properly installed, and all components are operable.

Manufacturer's literature from:

- Advanced Electrical Applications
- Anderson Cornelius
- Andover Controls
- Atlantic Energy Technologies
- Barber Coleman
- Beckman
- Climatron
- Computer Sciences Corporation
- Daytronic
- Detection Systems
- Honeywell
- HSQ Technology
- Margaux Systems
- MCC Powers
- Raytheon
- Staefa Control
- Tano
- United Technologies
- Westinghouse

APPENDIX "D"

SAMPLE DDC QUESTIONNAIRE

I. DEFINITIONS

1. Direct Digital Controller (DDC) - Computer based equipment designed to directly modulate a controlled device to obtain a desired set point. The DDC can interface with either electronic or pneumatic devices.

2. Central Computer - An independent computer system that can interface with a DDC. The computer contains a central processing unit, volatile and non-volatile memory. The central computer's functions are likely to include central monitoring, control and diagnostics of the DDCs.

3. Applications Programs - Set of instructions for controlling equipment based on a set of conditions that may vary over time. For example, the start/stop applications program starts up and/or shuts down equipment according to the time of day and the day of the week.

4. Open Loop Control - A control method where the computer can send commands to control points, but no information can be received from the field.

5. Closed Loop Control - A control method where a sensor continuously feeds information about a variable back to the controller.

II. CONFIGURATION

1. Can your DDC equipment function as a stand-alone system (without a central computer)? (Yes/No) ________

2. Can the DDC equipment interface with other manufacturers' central processing systems? (Yes/No) ________

   If yes, which systems? ______________________________

   ____

   ____

3. Does your DDC System standard configuration have a central computer system available? (Yes/No) ________

4. Do you have more than one size DDC that relates to the complexity of the control functions and/or I/O requirements. Please describe each basic system type in terms of:

	Type 1	Type 2	Type 3
Model No.	____	____	____
Number of Analog Inputs	____	____	____
Number of Analog Outputs	____	____	____
Number of Digital Inputs	____	____	____
Number of Digital Outputs	____	____	____
Number of Pulse Accumulators	____	____	____

	Type 1	Type 2	Type 3
Total Volatile Memory (RAM) Capacity			
Total Non-Volatile Memory (PROM) Capacity			
RAM (Kbytes) used for Operating and Diagnostic Software			
RAM (Kbytes) used for Default Parameters			
RAM (Kbytes) used for Application Software			
ROM (Kbytes) used for Operating and Diagnostic Software			
ROM (Kbytes) used for Default Parameters			
ROM (Kbytes) used for Application Software			

III. EQUIPMENT

1. Please indicate if your DDC contains the following (Yes/No):

	Type 1	Type 2	Type 3
On-Off Line Switch (for communication to a central system)			
Self Test Switch			
Reset Switch			
Real Time Clock			
Communications Interface (indicate types)			
Auto Answer/Auto Originate Modem for Remote Central Computer Interface			
Clock Battery Backup (indicate hours)			
RAM Memory Battery Backup (indicate hours)			

	Type 1	Type 2	Type 3
Power Failure Automatic Restart	______	______	______
Peripheral Ports (indicate quantity)	______	______	______
Multiplexer to Communicate with Local I/O	______	______	______
Multiplexer to Communicate with Remote I/O	______	______	______
Digital Input	______	______	______
Digital Output	______	______	______
Analog Input	______	______	______
Analog Output	______	______	______
Pulse Accumulator Input	______	______	______
Built-in Hardware Diagnostic and Programming Panel	______	______	______
Built-in I/O	______	______	______
Remote I/O via MUX	______	______	______
Local Display and Control Panel at DDC ________	______	______	______

Other (please List) ______________________________

____

____

2. What type of processor is used?

		Type 1	Type 2	Type 3
8 bit	________	______	______	______
16 bit	________	______	______	______
32 bit	________	______	______	______

3. What type of support equipment is required at the DDC for:

Reprogramming __________

Diagnostics __________

4. How many of the following can your DDC equipment handle?

	Type 1	Type 2	Type 3
Model No.:	______	______	______
Analog Inputs per Control Loop	______	______	______
Digital Inputs per Control Loop	______	______	______
Analog Outputs per Control Loop	______	______	______
Digital Outputs per Control Loop	______	______	______
Control Loops	______	______	______
Pulse Accumulator	______	______	______

5. With respect to the previous question, how does the memory requirements for application programs affect the number of control loops that each DDC can handle? If required please attach additional pages to answer this question. ________________

____

____

____

____

____

6. What is the "rule of thumb" used to calculate the number of DDC control loops and I/O points for each type of DDC controller as a stand-alone unit if all of the following programs are implemented:

   Start/Stop, Scheduled Start/Stop, Day-Night Setback, Ventilation/Recirculation and Duty Cycling.

____

____

____

____

____

7. Is the equipment standardized so that it can be used for monitoring and/or control of any type of equipment using standard instrumentation signals? If not, what components are not standard? ______________________________

____

____

IV. SOFTWARE

1. What additional equipment and/or software is required for changing applications programs at the Central Computer? __________

____

____

____

2. How can each individual DDC be brought on line?

   With Central Computer? ________

   Without Central Computer (Stand-alone Mode)? ________

3. What equipment is needed to initially bring the DDC on line in a stand-alone mode?

   Portable programming and disgnostic device ________

   Central Computer ________

   Other (please specify) ________

4. What equipment is required for software diagnostics at the DDC?

Central Computer __________

Portable Diagnostic Device __________

Built into the Equipment __________

5. How is a new program installed in the DDC?

Central Computer __________

Portable programming device __________

Other (specify) __________

6. How are safeguards provided against unauthorized access? ______

____

____

____

7. What programming languages are provided?

At central system ____

____

At DDC ____

____

8. Are english-like words provided for operator interface? (Yes/No)

Central computer __________

DDC __________

9. What applications programs are presently available that can be implemented in a stand-alone mode in a DDC without data from the Central Computer.

	Off the Shelf	To be available (indicate year)
Scheduled Start/Stop	______	______
Optimum Start/Stop	______	______
Duty Cycling	______	______
Demand Limiting	______	______
Day-Night Setback	______	______
Economizer	______	______
Enthalpy	______	______
Ventilation/Recirculation	______	______
Hot Deck - Cold Deck Reset	______	______
Reheat Coil Reset	______	______
Steam Boiler Optimization	______	______
Hot Water Outside Air Reset	______	______
Chiller Optimization	______	______
Chiller Water Temperature Reset	______	______
Condenser Water Temperature Reset	______	______
Chiller Demand Limit	______	______
Lighting Control	______	______
Other (please specify)	______	______

10. What information or commands can be manually requested for display at the DDC either through a built in display panel or a portable programming and diagnostic device? (Yes/No)

Point Status ____________

Parameter Values ____________

Change of State without Command ____________

Change of State beyond allowed Limits ____________

Equipment Failure ____________

11. What information from the DDC can manually be requested and/or automatically displayed at the Central Computer?

Point Status ____________

Parameter Values ____________

Change of State without Command ____________

Change of State beyond allowed Limits ____________

Equipment Failure ____________

Other (list) ____________

____

____

____

____

V. TRANSMISSION MEDIA

1. What transmission media is used by the DDC for communication with the central computer?

	Min. Speed (Baud)	Max. Speed (Baud)
Coaxial cable	______	______
Twisted pair	______	______
Dedicated telephone lines	______	______
Dial up telephone lines	______	______
Fibre optics	______	______
Other (specify)	______	______

2. How many data transmission links can be handled by your DDC central computer system? What is the expected response time for a fully loaded system? ______________________________

____

____

3. How many DDC can be connected to a single 1200 baud telephone line to the Central Computer? ________

VI. INTERFACE/CONTROL

1. Can your DDC be interfaced with other manufacturer's EMCS using standard electronic interfaces (RS232, RS422, etc/) with protocol information provided with the DDC controller under a sub-licensing agreement? (Yes/No) __________

   If the DDC equipment cannot be interfaced with other manufacturer's EMCS equipment, please indicate the reason:

   a. No interface information can be made available. _______

   b. No standard interface is part of the DDC panel. _______

   c. Other (explain). ______________________________________

   ____

2. Can your DDC equipment interface with pneumatic and/or electronic control systems? (Yes/No) __________ . How is this accomplished?

   ____

   ____

3. What control modes can the DDC control equipment perform?

   Proportional __________

   Proportional/Integral __________

   Proportional/Integral/Derivative __________

   Other (explain) ____

   ____

4. What method does your DDC use for analog output?

Pulse width modulation with feedback ______

Proportional electric output to drive transducers ______

Other (explain) ______

______

5. What type of control loop can your DDC provide?

Open Loop ______

Closed Loop ______

Other (explain) ______

______

VII. POWER FAILURE/AUTO RESTART

1. In the event of power failure, at the DDC controller are the contents of memory lost in the following if no memory battery backup is available?

Operating System ______

Applications Programs ______

Operating Parameters ______

2. When power is restored at the DDC controller, can the equipment restart automatically without data and/or communication with the control computer if memory battery backup is provided? If not, what is required for restart?

____

____

____

3. What output failure modes are available when the DDC field panel fails?

	On	Off	Last Command	High Value	Low Value	Mid Range
Digital Output				N/A	N/A	N/A
Analog Output	N/A	N/A				

VIII. RELIABILITY/REPAIR

1. For DDC systems already installed in the field, what is the mean time between failures (MTBF)?

   Central Computer __________

   DDC Field Panels __________

2. For DDC systems already installed in the field, what is the mean time to repair (MTTR)?

   Central Computer __________

   DDC Field Panels __________

3. Can DDC repair/diagnostics be performed by trained owner personnel. What level of training is required? ____________________

____

____

____

____

4. What system boards of the DDC can be replaced in the field?

   CPU ________ Power Supply ________

   I/O Boards ________ Memory Boards ________

5. What spare parts need to be stored on-site to minimize the MTTR of the DDC when using the available diagnostic devices?

   CPU ________ Power Supply ________

   I/O Boards ________ Memory Boards ________

IX. DESIGN/TESTING

1. For a project requiring approximately 100 I/O points using a stand-alone DDC, what is your estimated lead time for:

   Shop Drawings ________

   Installation ________

   Checkout ________

2. What codes and industry standards do you use for:

	Data Transmission Lines	Power Lines	I/O Functions
Surge Protection	______	______	______
Overvoltage Protection	______	______	______

X. ENVIRONMENTAL CONDITIONS

1. What are the minimum and maximum environmental conditions allowable for the DDC field equipment?

Minimum Dry Bulb ______

Maximum Dry Bulb ______

Minimum Relative Humidity ______

Maximum Relative Humidity ______

AC Power Supply - Volts _____ Min/Max tolerance (volts) _____

XI. INSTALLATION

1. What building codes are your DDC installations expected to meet?

NEC ______________

BOCA ______________

NFPA ______________

XII. COSTS

1. What is the estimated equipment budget costs of the following DDC?

	Type 1	Type 2	Type 3
Stand-alone DDC with no I/O	______	______	______
Stand-alone DDC with fully implemented I/O (No instrumentation or controls)	______	______	______
Digital Output	______	______	______
Digital Input	______	______	______
Analog Input	______	______	______
Analog Output	______	______	______
Pulse Accumulator	______	______	______

2. What is the estimated average budget costs to program a DDC for stand-along operation?

Type 1 __________

Type 2 __________

Type 3 __________

3. What is the estimated installed cost differential between pneumatic control systems and control systems that utilize DDC controllers? ____

____

____

____

XIII. DDC SYSTEM INSTALLATION

Provide description of types, sizes and number of systems that have been installed and accepted by the user. ______________

____

____

____

____

XIV. TECHNICAL LITERATURE

Please provide three copies of technical data on your DDC equipment and software.

Sample Letter sent to DDC Manufacturers requesting verification of data.

Gentlemen:

The Army Corps of Engineers, Huntsville Division wishes to release the report on "State-of-the-Art Technology Review of Direct Digital Control Systems for Electrical and Mechanical Systems to personnel in the Department of Defense. This report includes tables that describe certain characteristics of your equipment that was provided by your company to Kling-Lindquist, Inc. in a questionnaire. Before the report can be released, the Corps of Engineers requires a letter from your company, giving them permission to release this information.

Please review the attached tables and indicate which data can be released for distribution throughout the DOD. Please cross out any information you do not want released and modify any data that has changed since these tables were developed.

If you have not responded by October 15th, the Corps will assume that all data can be released. Please send letters authorizing release of the attached data to Kling-Lindquist, Inc. in Philadelphia.

Very truly yours,

Jeffery Costol, PE
Manager of Projects

JC/th
cc: Frank Carlin

Encls.

COMPUTER SCIENCES CORPORATION

SYSTEMS DIVISION (703) 237-2000
6565 ARLINGTON BOULEVARD · FALLS CHURCH VIRGINIA 22046

October 9, 1984

KLING LINQUIST, INC.
2301 Chestnut Street
Philadelphia, PA 19103

Attention: Jeff Cosiol

Gentlemen:

Computer Sciences Corporation (CSC) hereby authorizes the release of the attached information about CSC INFOSCAN product.

If you have any additional questions concerning CSC or its product as it is applied to Direct Digital Control (DDC) please let us know.

Sincerely,

JAMES E. BUENING
Manager, Control Systems

JEB/lmg

Attachment

CLIMATRON
BUILDING AUTOMATION SYSTEMS
1370 Logan Avenue,
Costa Mesa, California 92626
(714) 540-4208

October 16, 1984

Mr. Jeffrey Cosiol, PE
Kling Lindquist, Inc.
2301 Chestnut Street
Philadelphia, PA 19103

Dear Mr. Cosiol:

Attached is the revised data on our Direct Digital Control Systems. I've also attached copies of the brochures for the CLIMATRON 2100 and 4000 Series Systems for your information.

If you have any questions regarding this information please give me a call. Thanks for extending our deadline.

Yours very truly,

CLIMATRON, INC.

Carter Williams
Vice President/Marketing

CW:bj

Enclosures

ENERGIST™

Energist, Inc., 4294 Lee Road, Cleveland, Ohio 44128 (216) 751-9344

October 5, 1984

Mr. Jeffrey Cosil, Manager of Projects
Kling Lindquist, Inc.
2301 Chestnut Street
Philadelphia, PA 19103

Dear Jeffery:

Enclosed please find copy of corrected data sheet for your use. Corrections have been highlighted in yellow.

Thank you for your exposure.

Sincerely,

Mark Stevenson,
ENERGIST, Inc.

MS/dd

Enclosure

Honeywell

October 1, 1984

Jeff Cosiol
Kling Lindquist Inc.
2301 Chestnut Street
Philadelphia, PA 19103

Dear Jeff,

Honeywell Commercial Division hereby does release the information regarding the direct digital control system information for use by DOD personnel.

Please note the changes made in tables 2/1, 2/2, 2/3, 2/5, and 2/7. The proper "Model Type" is R7510 rather than 7511. Please make these changes prior to issue.

Regards,

J. Dowlle
Mark. [illegible] Sales Manager
Commercial Division

JRD/blm

cc: Doyle Adams
C. Walker

HONEYWELL INC., HONEYWELL PLAZA, MINNEAPOLIS, MINNESOTA 55408, TELEPHONE 612/870-5200

Post Office Box 423
Milwaukee, WI 53201-0423
Tel. 414/274 4000

JAE-85-2

RECEIVED
JAN 11 1985
KLING-LINDQUIST, INC.

JOHNSON CONTROLS
Systems & Services Division

Dr. Francine Bomar
Kling Lindquist Inc.
Engineers
2301 Chestnut Street
Philadelphia, PA 19103

January 7, 1985

Dear Francine,

Thank you for seeking out an update on the state of the art technology survey for DDC.

Please make the following changes to our previously answered questionaire:

1) In table 2-2, change the total RAM to 48K and the PROM to 40K. Please eliminate the 6K under application software RAM and let the note "proprietary data" apply to all memory application.

2) In table 2-7, change the battery backup for the clock and RAM to 72 hours. This is our standard backup package now.

3) In table 2-8, change the mean time between failures for the DDC device to 17,000 hours. As you can note, this is a marked improvement over our previous data. It happens to be based on more then 3500 DDC units shipped.

We appreciate your interest. Please let me know if there are further questions.

Sincerely,

JOHNSON CONTROLS, INC.

John A. Enright

John A. Enright, PE
Manager of Technical &
Engineering Services
National Accounts Department

cc: Joseph L. Toland, JCI, Philadelphia
Jude Anders, JCI, Milwaukee

TA

RECEIVED
OCT 24 1984

October 22, 1984

KLING LINDQUIST INC.
2301 Chestnut Street
Philadelphia, Pa. 19103

Attn: Mr. Jeffrey Cosiol, PE
Manager of Projects

Dear Mr. Cosiol, PE
Manager of Projects

Dear Mr. Cosiol,

Regarding your letter of September 25, please find enclosed the tables of questionaries.

Sincerely yours,

Mac Dierf
Manager
Computer Systems

MD/aw

T[illegible] & AN[illegible]ON INC • 652 Glenbrook Road P.O. Box 2519 Stamford CT 06906-0519 • Phone (203) 324-0106 • Telex 643614

RAYTHEON

RAYTHEON SERVICE COMPANY

A SUBSIDIARY OF RAYTHEON COMPANY

SPENCER LABORATORY
2 WAYSIDE ROAD
P.O. BOX [illegible]
BURLINGTON MA 01803 U.S.A

TEL: 617-272-9300
TWX: 710-332-0517
TELEX: 094-9490

JAC:eag:9312-217
EM: 914

3 October 1984

Kling Lindquist Inc.
[illegible] Chestnut Street
Philadelphia, PA 19103

Attention: Mr. Jeffery Cosiol

Subject: Energy Monitoring and Control Systems

Gentlemen:

We have received and reviewed the Kling Lindquist Inc. letter dated September 25, 1984 which requests permission for use of certain technical information related to Raytheon Service Company's Energy Monitoring and Control Systems. Raytheon Service Company hereby authorizes the use of the previously provided technical information in the planned DOD publication.

We request that the publication contain an accurate identification of the source of the information. Perhaps, the publication should note that if the reader wishes to obtain more complete technical information, he should contact:

Raytheon Service Company
Burlington, Massachusetts
[illegible] Marketing

In addition, Raytheon Service Company would like to receive a copy of the proposed publication. Should additional information be required, then please contact the undersigned.

Very truly yours,

RAYTHEON SERVICE COMPANY

Joseph A. Clarke

Joseph A. Clarke
Contract Administrator

END

FILMED

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DTIC